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MANUFACTURING AND ANALYSIS OF ALUMINIUM BASED MMC USING AL/SIC/COCONUT & BAGASSE ASH

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ABSTRACT
Pumps are an integral part of any water or fluid movement related applications. Number of parts in a pump are prone to corrosion. Those parts material need to be replaced with corrosion resistive material like Aluminum. Corrosion in pumps results from chemical reactions between the pumped fluid and exposed metal surfaces. Replacing pump parts can be expensive. So we need to find another solution than replacement. To protect these parts of the pump, we need to use materials that are resistant to corrosion or the environment around it. Aluminium has excellent corrosion resistance because it spontaneously forms a thin but effective oxide layer that prevents further oxidation. Aluminium-based metal matrix composites (AMMCs) have gained significant attention in recent years due to their unique combination of properties, making them suitable for a wide range of applications. AMMCs exhibit exceptional mechanical properties compared to pure Aluminium, including enhanced strength, stiffness, wear resistance, and fatigue properties. Additionally, AMMCs can exhibit improved thermal conductivity, electrical conductivity, and corrosion resistance, depending on the choice of reinforcement materials. The properties of AMMCs can be tailored by adjusting the composition, size, and volume fraction of the reinforcing phase. Hence, developing an Al based MMC using natural fiber reinforcement for pump parts is the aim of this project.
Keywords: MMC, coconut ash, bagasse ash, Aluminium, Silicon carbide.

I. Introduction

Generally, composites are macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composite materials are used in the manufacture of automotive components such as automotive panels chassis etc. and aerospace components like wings, fuselages etc. [1–6]. Recently, metallic matrix is an essential constituent for the fabrication of metal matrix composites (MMCs). Research and development of MMCs have increased considerably in recent years, due to their comparable strength and offered resistance to wear, corrosion and fatigue. Composites are being used in all types of applications requiring specific needs. Metal Matrix composites can be formed to meet specific special needs of a particular application. The present research work in the field of composites leads to an Aluminiumbased MMC which has been designed for applications requiring anti-corrosive material properties. As Aluminium in its base form is resistant to corrosion but also expensive as well as possesses less tensile strength than most other metals, it is necessary to upgrade it by forming a composite having aluminium as matrix and suitable reinforcing materials to increase its strength. Research in this field has shown that using Silicon Carbide powder as a reinforcing material can increase the tensile strength of the base metal by almost 25%. Hence Silicon Carbide is used as the primary reinforcement for advancement in tensile strength of the end composite. However as aluminium and silicon carbide are both costly materials so to decrease the overall cost of the end composite, cost efficient materials which are also corrosion resistant needs to be present in the end composite.

Natural wastes such as coconut shell ash and bagasse ash that are also currently being used in the concrete structures were selected to be the secondary reinforcing materials. It is also noticed that these natural wastes can also increase the tensile strength of the end composite.
AMCs have found wide applications in our daily life. There are some advantages in using particles reinforced AMCs materials than unreinforced materials such as- greater strength and high specific modulus, improved stiffness, light weight, low thermal expansion coefficient, high thermal conductivity, tailored electrical properties, increased wear resistance and improved damping capabilities. Reinforcing constituents can be incorporated within the matrix in the form of particles, short fibres, continuous fibres or mono filaments. Now it is used in aerospace, thermal management areas, industrial products, automotive applications such as engine piston, brake disc etc. In order to reduce the density and weight of the aluminium matrix reinforced with SiC, addition of low density materials is suggested recently. Fly ash (FA) available in large quantities in thermal power stations and ash produced by the combustion of agricultural residues (bamboo leaf ash (BLA), rice husk ash (RHA), and coconut shell ash (CSA)) are recommended as reinforcements to produce composite materials due to their low density and superior mechanical properties. The challenging part of the MMCs is the cost of the composite which depends on the reinforcement as well as the matrix materials. Hence there has been an increasing demand for the low cost reinforcements. The previous studies on the low cost reinforcements were like Kankara clay, fly ash, red mud reinforced to Al-Si alloys which gave the improved mechanical properties reducing the densities.

II. Literature review

Milind S. Mhaske&Uddhav M. Shirsat (2020)[1] ,In this paper, the study of mechanical and microstructural properties of Al-SiCcomposite manufactured by different processes under different conditions and study oftheir mechanical and microstructure properties. AMC's can be produced by differentmanufacturing methods such as Stir Casting, Powder Metallurgy, Squeeze Casting, andInfiltration. In this paper, focusis given to produce Al-SiC by powder metallurgy and stircasting, and compare their results.The results are compared using grey relationapproach and various mechanical properties such as density, porosity, hardness,compressive strength and tensile strength are studied. Aluminium is used as base metalmatrix of grade LM25 with Silicon Carbide particles as reinforcing material with 5%,10% and 15% by weight. Sijo M T& K R Jayadevan (2018)[2], To study various stir casting process parameters and to optimize them to achieve goodmechanical characteristics and uniform mixing of reinforcement. The experimentalsetup is asfollows - Cylinder crucible with 120 mm diameter. Blade is made of cast steelstrip of 25 MM with and 2 mm thickness. Length of the blade is 14 mm, 20 mm and 30mm and are weldedaround rotor of 20 mm diameter. Blade geometries used are 3-blade geometry, 4-blade geometry and 5-blade geometry. Stirrer speed is changed from50 rad/sec, 100 Rad/sec and 150 Rad/sec. Volume fraction of reinforcement SiC is 10%,20% and 30%. Diameter ratio, which is ratio between diameter of Crucible to diameterof stirrer blade, is 1.5, 2 and 2.5. Aluminium grade used is LM 6 and silicon carbide of 5-micrometre average size is used as reinforcement. For casting, Aluminium is preheatedto 450 degrees Celsius and SiC was preheated to 2000 degrees Celsius. To melt thealuminium, the temperature was increased to 750 degrees Celsius and the SiC particleswere added. Lalit N. Wankhade et.al (2021) [3] , In this study, 3 specimens of aluminium metal matrix composite having 0, 2.5 and 5%by weight of silicon carbide were prepared and their wear behaviour wasanalysed. Aluminium of grades 7075 is used and reinforcing material is silicon carbide.Magnesium of 1-2% by weight is also used as a degassing agent. Weight fraction of SiC is0%, 2.5%, and 5%. Load applied is 50, 100 and 150 N. Sliding distance is 500, 1500,2500 mm. T. Sathish et.al (2021) [4]**,** The effect of Magnesium oxide and silicon carbide in Aluminium AA6262 composite onmechanical properties such as hardness, impact strength, tensile strength andpercentage elongation is studied. Percentage of matrix Aluminium AA6262 is kept at88% and in the rest 12%, percentage of MgO increases from 3%-9% and simultaneouslypercentage of SiC decreases from 9%-

3%. D. Muruganandam et.al (2020) [5], This study inspects the change in mechanical properties of AMC due to changes in thepercentage composition of reinforcing SiC particles in it. Four samples were studiedwith percentage of aluminium decreasing from 97% to 88% whereas percentage ofsilicon carbide increasing from 3% to 12%. The sample with 88% Al6061 and 12%Silicon carbide produced better results as compared with other samples giving values oftensile strength 89 Mpa, percentage elongation of 5.98 %, hardness of 41.5 BHN, Impactstrength of 25 Nm. J. Chandradass et.al (2020) [6], Aluminium metal matrix composite having 5% SiC, 7% SiC and 7%SiC/3% Al2O3 byweight were prepared and their mechanical, microstructural and wear characteristicswere evaluated. The manufacturing parameters were stirrer speed = 650 rpm, stirringtime = 10 min, stirring temperature = 750 degree Celsius, feed rate = 0.8 g/sec and Impellerblade angle = 29 degrees. The results showed that the sample with 7% by wtSiC and 3%by wt Al2O3 showed maximum tensile strength of 134.3 N/mm^2 which is 27% morethan that of normal unreinforced Al6061. The sample with 7% by wtSiC and 3% by wtAl2O3 showed maximum hardness of 35 HV, which is 25% more than that of normal unreinforced Al6061. Lavepreet Singh et.al (2021) [7], This aim of this study is to evaluate properties of Al-SiC composite with 0-5% by weightof reinforcing SiC and to study the effect of increased stirring time on the mechanical aswell as microstructural characteristics. The manufacturing initiates by preheating of SiCat 200 degree Celsius for 2 hours. Aluminium is melted at 770 degrees Celsius and 4blade stirrer stirs the mixture for 20 min at 550 rpm. Results show that the hardnessvalue obtained by 5% by weight of SiC is 39.23 BHN which is 31% more than the samplecontaining 0% SiC. Due to increased stirring time, there is uniform distribution ofreinforcement and grain boundaries are formed. Ashish kumar et.al (2020) [8], This study compares the mechanical and wear characteristics of aluminium matrixcomposite with grade of aluminium LM24 and reinforcing materials as silicon carbideand graphite. The Materials used are Aluminium LM24 (Al + 8%Si + 4%Cu + 3%Mg),Graphite at 2% constant, Silicon carbide having percentages 0%, 3%, 6%. The testingparameters are sliding distances of 1256.56 m and 2513.27 m, sliding velocities of 1.047m/s and 2.094 m/s, loads of 10N, 30N and 50N. For casting of samples, aluminium ismelted at 740 degrees Celsius and stirred for 5 min at 300 rpm. P. Rasagopal et.al (2020) [9] , In this study, attempt has been made to study the effect of various machining parameters such as speed, feed and depth of cut on cutting force required and surface roughness obtained of aluminium based metal matrix composite. Composite matrix base is Al 7075 and reinforcements used are SiC and B4C both in the percentages of 1%, 2% and 3% each. Stir casting method is used to manufacture the MMC. Machining parameters set were speed of 1000, 1500 and 2000 RPM, Feed of 30, 60 and 90 mm/min and depth of cut of 1, 1.5 and 2 mm. Giulia Scampone et. al (2021) [10], Experimental and numerical investigations of oxide-related defectsin Al alloy gravity die castings.The paper presents a comprehensive study on the formation of oxide-related defects in aluminum alloy gravity die castings. The study employs both experimental and numerical techniques to investigate the causes and mechanisms of such defects. In this literature review, we will discuss the main findings and contributions of the paper.The experimental section of the paper describes the techniques used to produce the castings and the methods employed to analyze the defects. The study uses a gravity die casting process to produce test specimens with different levels of oxide content. Vikas Verma et.al (2019) [11] , In this current situation fly ash is very harmful to environment and as it is solid so it can be use in Al MMC. It affects structural and functional properties of Al MMC. For this experiment the material which are get used are fly ash particles (10 micron), Al2O3 particles (300-400 microns) in melted Al. Al of grade 7034 is used because of it's chemical composition in weight percent.In this research paper the Al2O3 and fly ash mixed in various compositions to make Al MMC. The mixture of Al2O3 and fly ash gets stirred and then get fill into a preheated die. It is also observed that holding time, holding temperature and stirring speed are significant variables in stir casting process. Also in we increase holding time, holding temperature and stirring time then there is decrease in porosity. The mould was also taken tom hydraulic press to reduce porosity and improve bonding between Al, Fly ash, Al2O3 particles. After manufacturing and testing it is observed that the density of MMC was 96% and the stirring results in uniform distribution of particles and it is observed that reinforced particles forms dendrite structure during casting. Hardness, tensile and bending strength of MMC get tested after manufacturing. Mechanical properties of Al based MMC gives better results after adding fly ash and 12wt%of Al2O3. Hardness, strength and bending strength gets increase. Increased percentage of Al2O3 and fly ash increase wear resistance as it enhances it's hardness. B. Vijaya Ramnath et.al (2021) [12] , In this paper, a review of various factors affecting the mechanical properties of Al based MMC's is done. Aluminium has low density, better thermal stability and solid-state diffusivity is good which results in it being the optimum choice to be used as matrix. Reinforcement selection can be done on the basis of mechanical properties, melting point, thermal and electrical conductivity and end requirement of composite. Study of various AMMC's showed that Silicon Carbide exhibited best properties for most applications as it increases the tensile strength, hardness, Impact strength as well as it distributes evenly in Aluminium matrix when manufactured by Stir Casting method. However, addition of hard ceramic reinforcement leads to increased tool wear. Moreover, Feed rate was found to be the major factor affecting surface roughness of machined AMMC. Prashanthakumar H.G et.al (2019) [13], In this research paper information of combination of Al alloys and SWCNT (single wall carbon nanotube)/ MWCNT (Multi wall carbon nanotube) is given. This alloy is tested for it's tribological properties and other properties like effect of friction, wear and structural damage on carbon allotropes during different testing. For this the material used are Zinc, magnesium, copper, silicon, chromium, iron, titanium, manganese, Al6061(balanced). CNT increases the wear resistance of material slightly. The wear rate of Al 6060 is greater then wear rate of Al 6061. CNT's composite are restricted to be in line contact. T. Balarami Reddy et.al (2019) [14],To study the behavior of Al MMC with Cu particles reinforced in it. For this the material used are Aluminum, Copper, Manganese, zinc, lead. Copper evenly get distributed in the MMC by stir casting. Higher the weight % of copper higher the hardness of material. Copper results in increase in hardness but decrease in tensile strength as the weight % get increase. Reinforcement of copper in Al MMC will increase MMC's hardness but will also increase ductility.

III. Manufacturing of Al based Composite :

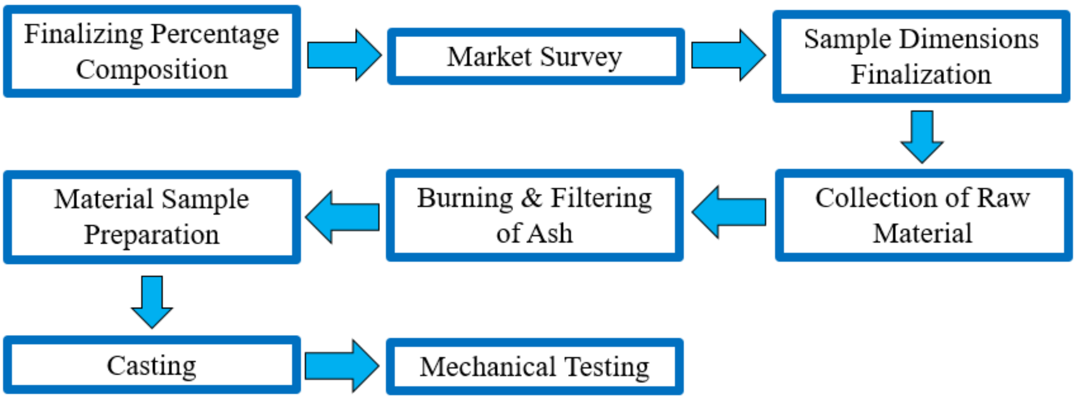

Figure 1: MMC manufacturing process in brief .

As concluded through literature survey, Silicon Carbide is used as a primary reinforcing material to increase tensile strength of composite. Bagasse ash and Coconut shell ash are used as fillers to reduce overall cost of end composite. Below table shows finalized percentage volume fraction of reinforcing materials.

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No.	Aluminium (%)	Silicon Carbide powder (%)	Coconut Shell Ash (%)	Bagasse Ash (%)
1	82	6	6	6
2	80	6	6	8
3	80	6	8	6
4	78	6	8	8
5	79	9	6	6
6	77	9	6	8
7	77	9	8	6
8	75	9	8	8
9	76	12	6	6
10	74	12	6	8
11	74	12	8	6
12	72	12	8	8
13	73	15	6	6
14	71	15	6	8
15	71	15	8	6
16	69	15	8	8

Table 1 - Sample Composition (%)

As per the data obtained from literature survey, verification of various practical aspects was needed to determine materials, sample size as per testing requirements, manufacturing considerations, etc. Initially the availability of materials is checked as per the powder size requirement and material vendor is finalized. Then the sample size required for tensile as well as microstructure testing is finalized after discussing with testing laboratory. After this, the casting vendor is contacted for manufacturing considerations as well as for the losses that may occur during casting.The samples to be used for testing were decided as follows:-

1) Rod – For tensile testing
2) Plate – For checking machinability by machining slots with VMC as well as to measure surface roughness and to provide a sample for microstructure study.

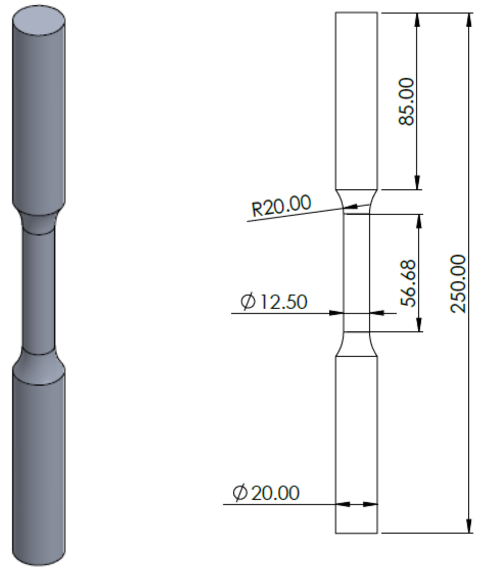

Fig 2 : Composite testing rod

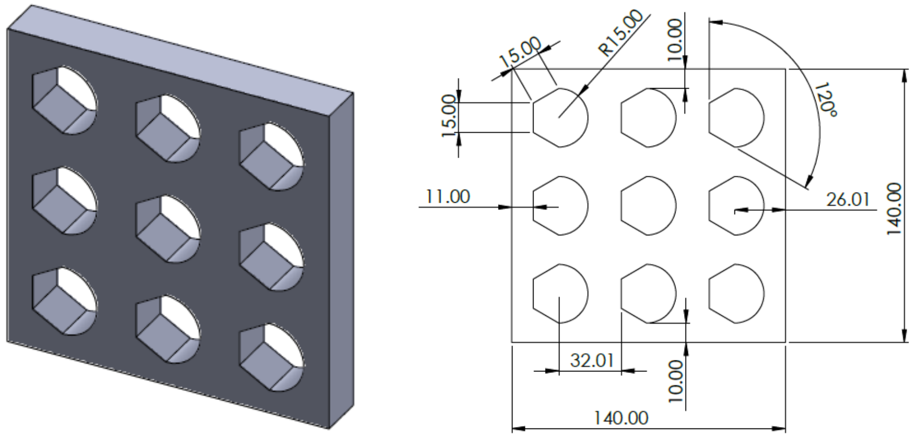

Fig 3: Machining workpiece.

2.4 Preparation of Reinforcement Materials

1) Collection of Raw Materials - Coconut Shells and Bagasse is collected and dried.

Fig 4 Coconut shells

Fig 5 Dried Bagasse

2) Burning of Raw Material – Dried Coconut Shell and Bagasse is burnt in presence of open air so that ash is formed and formation of coal is prevented.

Fig. 6 Burning of CSA & Bagasse

3) **Filtering of Ash** – Ash formed after burning is filtered to 80 μm by use metallic sieve.

Fig.7 Filtering CSA & Bagasse Ash

Fig.8 Filtered Ash

LM25 aluminum is a widely used alloy in various industries due to its excellent combination of mechanical properties, casting characteristics, and corrosion resistance. It belongs to the aluminum-silicon (Al-Si) family of alloys and contains approximately 7% silicon, along with other elements such as copper, magnesium, and zinc. LM25 aluminum offers good strength, high ductility, and superior thermal conductivity, making it suitable for a range of applications. The alloy's favorable casting properties, including good fluidity, low shrinkage, and excellent machinability, contribute to its popularity in the casting industry. Additionally, LM25 aluminum exhibits good resistance to corrosion and is capable of maintaining its mechanical properties even under harsh operating conditions.

Fig. 9 Aluminum LM25

2) Silicon Carbide powder:-

Sic powder is commonly used as a reinforcement material in the production of high-performance composites. When combined with a matrix material, Sic powder enhances the mechanical properties of the composite, including stiffness, strength, and wear resistance. The addition of Sic powder can significantly increase the load-bearing capacity and durability of the composite structure. Sic-reinforced MMCs offer improved mechanical properties, including enhanced strength, stiffness, and thermal conductivity compared to the base metal. It was observed in the literature survey that adding Sic increases the tensile strength of base metal by up to 25%. So, Sic of particle size 50 μm is used as a primary reinforcing material to increase tensile strength of end composite.

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Fig. 10 - Silicon Carbide powder

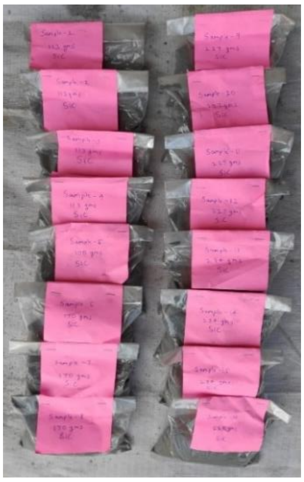

Fig. 11 – SiC samples

3) Bagasse ash:-

Bagasse ash is a byproduct obtained from the combustion of bagasse, which is the residue left after sugarcane stalks are crushed to extract juice. Bagasse ash can act as a reinforcing material in composites. By adding bagasse ash particles to a polymer matrix, the composite's strength and durability can be increased. The resulting composite material exhibits improved mechanical properties, including tensile strength, flexural strength, and impact resistance. Bagasse ash is mainly used as a filler to reduce overall end cost of composite. Size of bagasse ash, which we have used, is 80 µm.

Fig. 12 – Bagasse ash

Fig. 13 – Bagasse samples

4) Coconut shell ash:4

Coconut shell ash has natural hydrophobic properties, which can be beneficial in controlling water absorption in composites. When added to a matrix, it can help reduce the absorption of water or moisture by the composite material, thereby improving its dimensional stability and resistance to degradation caused by water exposure. It improves the stiffness, strength, and dimensional stability of the material. The addition of coconut shell ash fillers can also contribute to reducing the overall cost of composites. Size of Coconut shell ash used is 80 µm.

Fig. 14 – Coconut Shell Ash

Fig. 15 – CSA samples

As per the data obtained from manufacturer, a difference of 40 Mpa was observed between the samples that were gravity die casted and those manufactured by sand casting. Also as observed from samples, the samples manufactured by sand casting had minute pores which may lead to crack initiation early during tensile testing so, gravity die casting method was finalized. Gravity die casting, also known as permanent mold casting or chill casting, utilizes a reusable metal mold, typically made of steel or cast iron, which is preheated to a specific temperature. The mold is coated with a refractory material to enhance its heat resistance and prevent the adhesion of molten metal. The mold is then clamped together, and the molten metal is poured into it, allowing gravity to fill the cavity. The molten metal is left to solidify, and once cooled, the mold is opened to extract the cast component. In case of MMC's manufactured by gravity die casting, aluminum is melted above 700 °C and the furnace is turned off. Addition and mixing of preheated reinforcements takes place in this period and the furnace is again turned on allowing the reinforcements to mix and disperse in the matrix of aluminum.

Fig. 16 – Casting setup

Fig. 17 – Final Material Samples

Fig. 18 – Melting of Al

Fig. 19 – Addition of Reinforcements

Fig. 20 – Casted plate and rod

IV. Result and Discussion

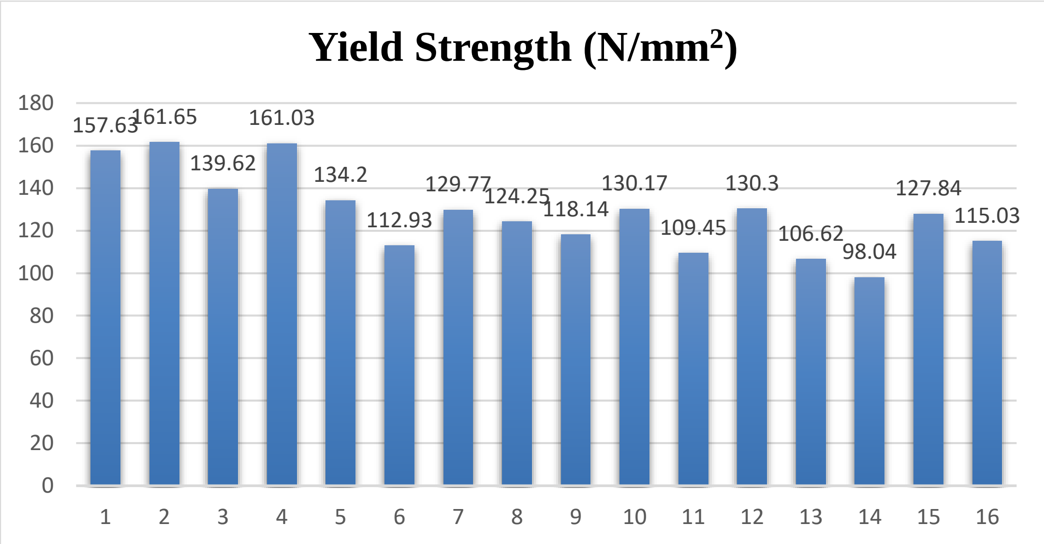

Fig 21 – Yield strength Vs Sample Number

Table 3.1 Yield Strength & hardness values

Plate number	Yield Strength (N/mm^2)	Hardness (HBW)
Plate 1	157.63	53.8
Plate 2	161.65	46.1
Plate 3	139.62	56.1
Plate 4	161.03	54.8
Plate 5	134.20	55.8
Plate 6	112.93	53.8
Plate 7	129.77	53.1
Plate 8	124.25	56.8
Plate 9	118.14	52.8
Plate 10	130.17	54.8
Plate 11	109.45	58.3
Plate 12	130.30	56.8
Plate 13	106.62	56.1
Plate 14	98.04	58.3
Plate 15	127.84	54.1
Plate 16	115.03	58.3

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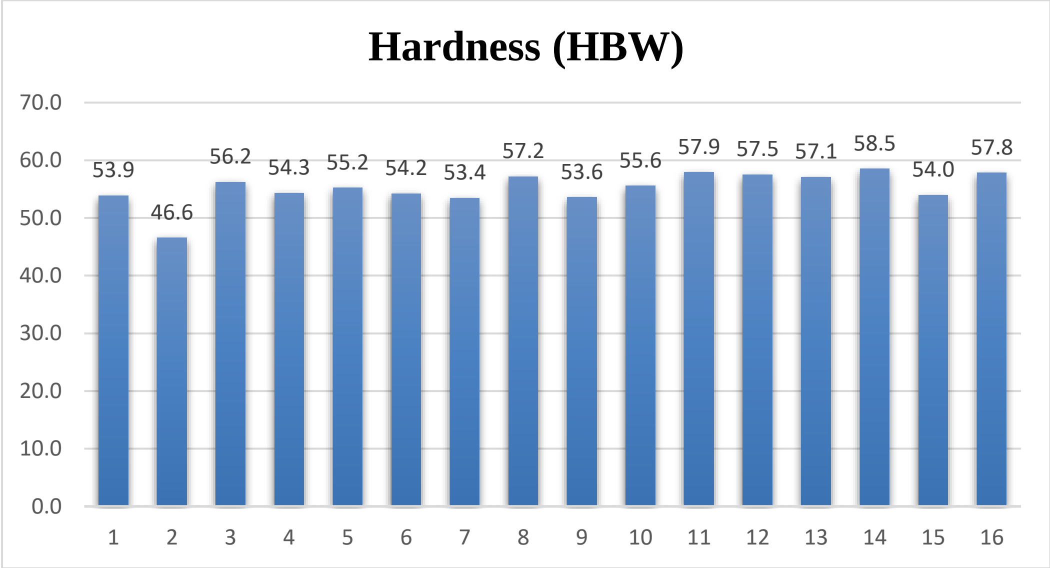

Fig 22 – Graph of Hardness Vs Sample Number

Microstructure study – Microstructure study is done for all samples using 'ASM Handbook Vol. 9:2004' test method. A polished sample of size 20 mm x 20 mm is used transverse orientation. The etchant used is Hydrofluoric acid and the magnification done is 200X. Below is the microstructure of sample 4. Microstructure shows interdendritic network of eutectic silicon particle (gray) and Mg_2Si (black) in matrix of Aluminium.

Fig. 23 Sample Composite Microstructure

V. Conclusion

In order Based on the presented work, following conclusion are drawn :

- Aluminum based MMC is prepared with Aluminum as parent material and Silicon carbide (SiC), Ash of Coconut and Bagasse ash (Al/SiC/A).
- Sixteen composites were prepared with different possible compositions.
- All samples were tested for getting the strength and hardness.

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